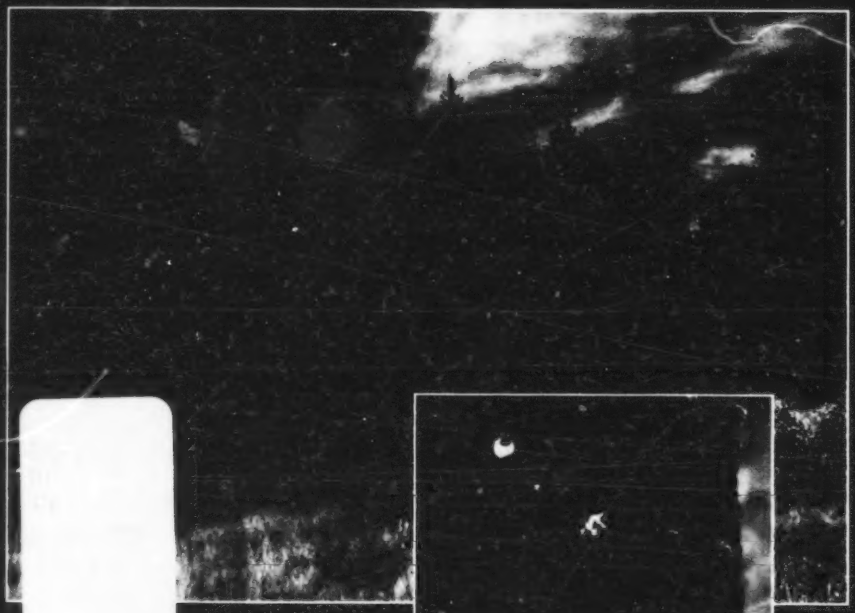
KAMLOOPS FOREST REGION



Strategies and Tactics for Managing

The Mountain Pine Beetle *Dendroctonus ponderosae*

101-06408/

STRATEGIES AND TACTICS FOR MANAGING THE MOUNTAIN PINE BEETLE, *Dendroctonus ponderosae*

LEGISLATIVE LIBRARY OF BRITISH COLUMBIA
3 3298 00246 0971

B.C. Forest Service
Kamloops Region Forest Health

edited by

L. E. Maclauchlan
and
J. E. Brooks

October 2000

LEGISLATIVE LIBRARY
VICTORIA BC V8V 1X4 JUL 1 1 2001

Acknowledgments

The strategies and tactics described in this document are the results of the knowledge and dedication of those individuals who came together under the auspices of the Mountain Pine Beetle Task Force with the intent to improve the manner in which the mountain pine beetle is managed in the Provincial forest. Tom Lacey chaired the group which included Mike Geisler, Peter Hall, Jim Mottishaw, Les Safranyik, Rick Smith, Ron Unser, Lorraine Maclauchlan and Don Dobson.

Overall direction was provided by the Mountain Pine Beetle Steering Committee which was chaired by Phil Van Mol and included Howie Carter, John Borden and John Wenger. Finally, we appreciate the support of all District Forest Health staff who provided valuable input into this manual.

Contents

I Life and times of the mountain pine beetle 1
1. Dispersal 2
2. Colonization 3
3. Production 4
4. The role of semiochemicals 7
5. Symptoms of mountain pine beetle attack 8
II Strategies and Tactics 11
Strategies 12
1. Prevention (long-term) 13
2. Suppression 14
3. Maintain Low 16
4. Holding Action 17
5. Salvage 18
6. Abandon (no control) 19
Tactics 20
1. Survey/Assessment 20
A. Overview flights 21
B. Detailed surveys 21
C. Aerial photography 22
D. Ground detection 22
E. Hazard rating 23
F. Risk rating 28
G. Population prediction 28
2. Harvesting 30
A. Sanitation 30
B. Salvage 30
C. High hazard host removal 30
D. Harvest priority rating system 30
3. Single tree treatment 31
A. Small patch/single tree treatment 31
B. MSMA (monosodium methane arsenate) 31
C. Fall and burn 34
D. Preventative insecticide 34
E. Debarking 35
F. Helicopter logging 35
4. Baiting techniques 35
A. Contain and concentrate 35
B. Monitoring 36
C. Follow-up on single tree treatments 36
D. Stand and infestation parameters 36
Baiting techniques selection 37
5. Hauling restrictions 39
6. Access development 40

7. Beetle proofing 40
Criteria for selecting stands for beetle proofing 40
8. Silviculture treatments 42
A. Species manipulation 42
B. Age class manipulation 42
III Developing a mountain pine beetle management plan 44
1. Ranking BMUs 45
2. Timing and Scheduling 49
IV Definitions 51
Appendix I 55
V References 57

List of Figures

Figure 1. View of a drainage south of Princeton, showing current and past mountain pine beetle attack, and sanitation harvest 2
Figure 2. View of cross section of mature lodgepole pine killed by the mountain pine beetle 3
Figure 3. Diagram showing galleries and adults of *Ips pini* and *Dendroctonus ponderosae* 4
Figure 4. Mountain pine beetle parent gallery with inset showing eggs 5
Figure 5. Mountain pine beetle pupae and teneral adults 6
Figure 6. Semiochemical-baited lodgepole pine which has been mass attacked .. 8
Figure 7. Symptoms of mountain pine beetle attack 9
Figure 8. Pitch response of lodgepole pine to MPB attack: and adult *Dendroctonus ponderosae* and *Ips pini* 10
Figure 9. View of non-susceptible lodgepole pine and susceptible, older pine .. 13
Figure 10. View of susceptible lodgepole pine showing spot infestations of mountain pine beetle 15
Figure 11. View of a drainage in the south Okanagan, within a salvage BMU, showing past and current mountain pine beetle attack, and salvage harvest blocks 19
Figure 12. Two maps showing a section of forest cover map (1:30,000) in the Whipsaw Creek drainage 24, 25
Figure 13. Diagram showing stage of mountain pine beetle gallery construction that is optimum for treating with MSMA 32
Figure 14. Form used to calculate MSMA quantities for post-attack injection against mountain pine beetle 33
Figure 15. Example of MSMA-treatment data form 34
Figure 16. A stand that was beetle-proofed by the USDA Forest Service in South Dakota, USA 41

List of Tables

Table 1. Area of mature lodgepole pine killed by MPB in the Kamloops Regions 1
Table 2. Attack intensity classes for mapping mountain pine beetle during aerial surveys 21
Table 3. Recommended ground survey method and intensity 23
Table 4. Determining priority for action based on stand hazard and associated risk 28
Table 5. Mountain pine beetle management tactics 43
Table 6. BMU ranking form 48
Table 7. Annual schedule of mountain pine beetle management activities 49

I. LIFE AND TIMES OF THE MOUNTAIN PINE BEETLE

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), is the most important insect pest on lodgepole pine in western Canada. On average, 16,000 ha of mature timber are killed each year by this insect in the Kamloops Region, (Table 1), with large tracts of susceptible timber remaining. These stands are composed primarily of even-aged lodgepole pines that are past the natural rotation age, due largely to exclusion of fire for the past 50 years. The mountain pine beetle (MPB) and its primary host, lodgepole pine, are native to the Pacific Northwest. In addition to lodgepole pine, in British Columbia, the MPB attacks ponderosa, western white and whitebark pines (Furniss and Carolin 1980). The MPB is a very aggressive insect, placing entire pine stands at risk. MPB infestations often result in extensive tree mortality. Factors contributing to susceptibility include high stand density; species composition (high component of lodgepole pine); age (>80 years); elevation and aspect; and tree vigour (Safranyik *et al.* 1980). Weather is one of the most important factors influencing the population dynamics of *D. ponderosae* (Stark 1982). The weather conditions in the Kamloops Region are very favorable for MPB development and dispersal, particularly in the southern half of the Region, where summer temperatures are consistently high with low precipitation, and the winters are moderate.

Table 1. Area of mature lodgepole pine killed by MPB in the Kamloops Regions (Taken from F.I.D.S. Annual Reports 1987-95 and MOF data 1996-00).

Year	Affected Area (ha)
1987	19,000
1988	17,600
1989	21,100
1990	6,000
1991	19,000
1992	21,000
1993	19,925
1994	8,865
1995	8,865
1996	12,000
1997	19,200
1998	19,100
1999	30,700
2000	21,300

The impact of MPB is not limited to timber loss, but also impacts upon recreation and aesthetic values, range, fish and wildlife resources, and watershed management (Fig. 1). However, timber loss, and more importantly, the disruption of long-term forest management plans, is a major concern to forest managers and planners. Stream water and fisheries

can be affected by the killing of trees, modifying the water flows of a watershed by changing snow melt and water transportation patterns. Treatments of infested areas by control measures, such as timber harvesting and other treatments to rehabilitate areas, can further affect fisheries values and domestic use.

Thorough understanding of the biology and ecology of the insect will greatly facilitate management decisions. Over the last 25 years, numerous management strategies and tactics have been attempted in British Columbia. Current strategies and tactics for managing MPB are discussed in this manual.

Figure 1. View of a drainage south of Princeton, showing current and past mountain pine beetle attack, and sanitation harvest.

1. DISPERSAL

There are three main phases of a bark beetle's life history: dispersal, colonization and production. Adult beetles emerge from infested trees from mid-July through August, leaving distinctive exit holes in the outer bark. Emergence may occur over a period of several days to several weeks. Temperature and other environmental factors will affect beetle emergence. Generally, mountain pine beetle females emerge first to disperse and colonize new host trees. The dispersal phase of the MPB is the only time in its life history when the beetle is exposed to the environment and typically lasts less than 24 hours. Much natural mortality occurs during the dispersal phase when beetles are searching for and selecting hosts.

2. COLONIZATION

Colonization of the tree begins once the mountain pine beetle has accepted a new host. *D. ponderosae* feeds exclusively on standing, live pines. If the infestation level within a stand is endemic, i.e. at natural, often low, population levels, then mountain pine beetle may be thought of as a secondary insect. MPB generally attacks trees which are physiologically weakened, due to climatic or other environmental conditions. This often triggers population explosions and outbreak situations (Safranyik *et al.* 1980). Under epidemic conditions, *D. ponderosae* becomes a primary pest and invades and kills healthy, vigorous trees.

Once a tree has been accepted by the MPB, a series of events then occurs to ensure successful colonization. Trees have intense defensive capabilities, producing large amounts of resin which are toxic to the beetle. In order for insects to successfully overcome the defense mechanisms of a tree, large numbers of beetles must aggregate and attack within a very short time frame. This behavior is referred to as "mass attack".

Aggregation pheromones produced by the mountain pine beetle, and monoterpenes produced by the host tree, combine to attract other male and female *D. ponderosae*. Release of these semiochemicals and subsequent attraction of beetles produces a mass attack on a tree. Once mass attack is achieved, the production of repellent pheromones and stridulation (production of sound by friction) increases. These semiochemicals also attract parasites, predators and commensals of bark beetles.

Microorganisms such as the blue stain fungus, *Ceratocystis* spp., are introduced into the tree by beetles. The combination of gallery construction and fungal infection (Fig. 2) overcome the trees' defense system, while providing nutrients for the developing brood. The blue stain causes rapid degradation of the wood and therefore a decrease in timber value (Safranyik *et al.* 1980).

Figure 2. View of cross section of mature lodgepole pine killed by the mountain pine beetle, showing zone of *Ceratocystis* stain.

3. PRODUCTION

Mountain pine beetles bore through outer bark into the phloem tissue. Once they have successfully penetrated the phloem, brood gallery construction is initiated. Mountain pine beetles generally mate on the bark surface near the entrance hole or in a niche constructed just under the bark. The brood gallery is constructed in the phloem tissue and slightly etches the sapwood. Gallery shape is diagnostic of bark beetle species (Fig. 3). Occasionally during a summer season, mountain pine beetles re-emerge to initiate a second gallery. Care must be taken not to confuse the galleries and brood of other species of bark beetle. Another commonly encountered bark beetle in pine is the pine engraver, *Ips pini* (Fig. 3). *Ips* must not be confused with the mountain pine beetle and can be distinguished by morphological features (spines on the rear of its abdomen) and gallery shape (Fig. 3).

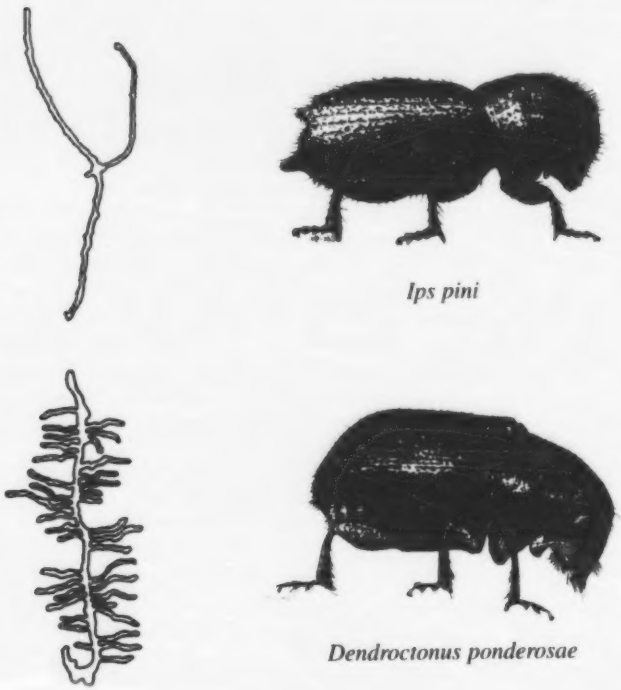


Figure 3. Diagram showing galleries and adults of *Ips pini* (top) and *Dendroctonus ponderosae* (bottom).

The male joins the female once the gallery has been successfully initiated. When mating has occurred, the male generally leaves the gallery. The female continues gallery construction, plugging the entrance hole with frass (insect excrement consisting primarily of macerated phloem). Sixty to eighty eggs are laid, singly in small niches carved out along the sides of the gallery (Fig. 4). Egg laying occurs in late July through mid-August (dependent on the weather).

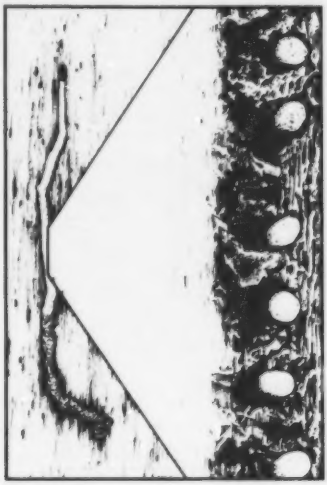


Figure 4. Mountain pine beetle parent gallery with inset showing eggs laid in niches.

Eggs hatch in 2 weeks and 1st instar larvae mine perpendicular to the parent gallery. First instar mining, combined with colonization by *Ceratocystis*, successfully cuts off translocation, thus girdling and killing the tree. *D. ponderosae* goes through 4 instars, overwintering as 3rd instar larvae. Development is completed the following spring. Mature larvae excavate a pupal chamber and pupation occurs in early to mid-summer. Pupae moult to teneral (immature) adults (Fig. 5). Beetles then feed on the *Ceratocystis* fungi within the pupal chamber for up to 2 weeks prior to emerging. This is known as maturation feeding, which is necessary for various maturation processes, such as flight muscle development. Finally, from mid to late July, mature beetles bore out of the bark and attack new hosts, thereby completing the cycle (Furniss and Carolin 1980).

Newly emerged beetles have only a brief time in which to locate and establish the suitability of hosts. A suitable host must have adequate moisture content, sufficient feeding stimulants and negligible toxic or inhibitory materials. Within 24 hours, flight muscles begin to degenerate, leaving the mountain pine beetle inextricably linked to the selected host

tree. As brood production and gallery construction progresses, flight muscles begin to regenerate. The more vigorous beetles of the population may re-emerge to disperse, select new hosts and establish second broods. Those insects capable of second brood production may significantly impact on beetle populations. The following summer, newly emerged beetles will re-initiate the entire host selection process.

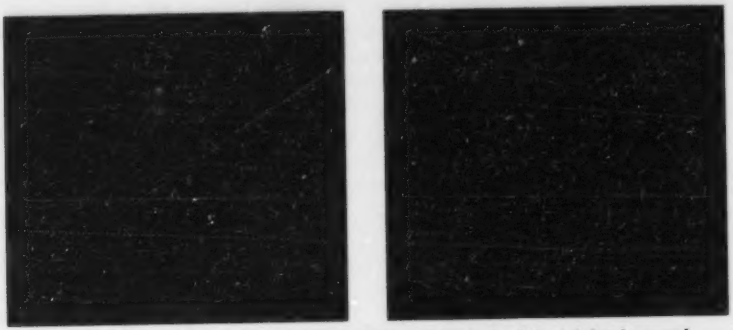


Figure 5. Mountain pine beetle pupae (left) and teneral adults (right) in pupal chambers showing coloration of sapwood by *Ceratocystis* fungus.

Many species of insects are associated with MPB on pine. Phytophagous insects compete for the limited resource, while commensals feed on microbes and dead insects within the brood galleries. Entomophagous insects feed on and parasitize scolytids. They have evolved the ability to utilize MPB-produced pheromones as kairomones, enabling them to locate and attack their prey. Predators and parasites have closely synchronized life cycles and are adapted to host finding in the earliest stages of scolytid attack. Through the manipulation of pheromone communication, other bark beetles such as *Ips pini* can successfully colonize host trees which are under initial attack by the mountain pine beetle, thereby inhibiting further colonization by *D. ponderosae*. Research into this competitive exclusion could lead to a new biorational approach to MPB management.

The role of predation, parasitism and disease in the population dynamics of the mountain pine beetle is not well understood. However, temperature affects both the rate of development and survival of the MPB. Optimum temperatures for growth and development of the MPB occur between 4.4 - 37.8°C. Cool summers prolong development and cause the broods to require 2 years for development. An extended life cycle exposes the immature stages to mortality factors for a longer period. Cool summer temperatures may cause the beetle flight to be late, and late flights decrease the chance of eggs hatching before winter. Survival of all stages of the MPB is reduced by unseasonably cold temperatures and extremely high summer temperatures. Therefore, when planning any suppression or control tactics, all the above factors must be taken into consideration to prescribe the most efficient treatment and to optimize efficacy.

4. THE ROLE OF SEMIOCHEMICALS

Bark beetles communicate with conspecifics by utilizing chemical messengers called semiochemicals. Pheromones are semiochemicals which induce a behavioral or physiological response in members of the same species (Borden 1982). Within the Scolytidae, aggregation pheromones, which cause male and female insects of the same species to aggregate at a host tree, play a major role in successful colonization of that host. When the desired density of beetles in a host has been attained, anti-aggregation pheromones (e.g. verbenone) are produced by the insects in order to limit the number of incoming beetles. These chemicals serve to regulate attack and population density in a given host.

Beetles, as well as the host tree, produce other chemicals known as allomones and kairomones, which serve as interspecific messengers. A kairomone is a chemical produced by one species and then used by another species for its own benefit, e.g. aggregation pheromones produced by mountain pine beetle are also attractive to their predators and parasites. Allomones are adaptively beneficial for the organism producing them. For example, mountain pine beetle might produce an allomone, thereby deterring another potentially invading scolytid species.

Several pheromones are employed by mountain pine beetles to achieve mass attack. These compounds act synergistically to attract large numbers of beetles to the tree. Pioneer beetles are the first insects to attack a living tree and to produce aggregation pheromones. Generally, one sex acts as a pioneer. MPB females are the pioneering sex. A suitable host must be located using primary attraction, e.g. by responding to a volatile produced by the host tree (kairomone) or to a visual cue such as the vertical silhouette of a standing pine. It is still uncertain as to whether hosts are located through primary attraction or through chance. Most likely, *D. ponderosae* is first attracted visually to the host, and then is stimulated by feeding. The second wave of beetles leaving their overwintering sites respond to pheromones produced by the pioneer beetles at the living host. This is known as secondary attraction. Beetles responding to secondary attraction have increased chances of success due to the proven nature of the host and reduced dispersal time.

In the dispersal/colonization phase, beetles of both sexes respond to the complex of beetle-produced pheromones and host-produced kairomones that comprise the various components of secondary attraction (Borden 1982). The intensity of this stimulus will depend on the number of pheromone-producing beetles boring into the host and whether or not they have been joined by beetles of the opposite sex. Olfactory stimuli may be supplemented by visual stimuli. The use of semiochemical baits simulates natural pheromone production and causes concentration of beetle attack on select trees or groups of trees. The end result is a "mass attack" of the suitable host (Fig. 6).

Pheromones produced by *D. ponderosae* include exo-brevicomin, endo-brevicomin, and trans-verbenol. Alpha-pinene, myrcene and terpinoline are kairomones produced by the host tree. Trans-verbenol is attractive to both sexes in the field in conjunction with alpha-pinene, a common monoterpene present in the host. Exo-brevicomin is attractive with other components at low concentrations and inhibitory at high concentrations. Endo-brevicomin inhibits response. Myrcene and terpinoline act as synergists for trans-verbenol. Commercially available MPB baits contain two components, alpha-pinene and trans-verbenol (Borden *et al.* 1993).

Figure 6. Semiochemical-baited lodgepole pine which has been mass attacked by the mountain pine beetle.

5. SYMPTOMS OF MOUNTAIN PINE BEETLE ATTACK

Symptoms of mountain pine beetle attack are evident on the bole, under the bark and by the coloration of crown foliage. The first sign of attack is beetles boring into the bark and pitch exuding at the point of attack (Figs. 7 and 8). Occasionally, reddish-brown sawdust in bark crevices and a small amount of pitch mixed with frass at the entrance of the beetle gallery are the only visible signs of attack. A ring of boring dust and frass can be seen around the base of attacked trees (Fig. 7). When an attacking beetle cannot successfully overcome the trees' defenses, the beetle will be "pitched out". A pitch-out can be distinguished by very clear to white pitch, often with the beetle trapped in the resin.

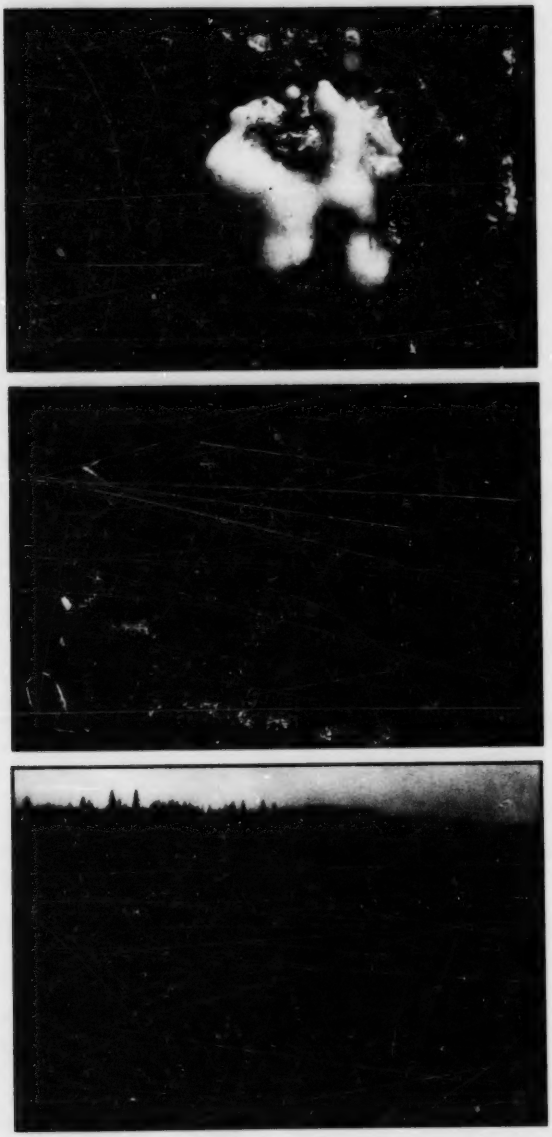
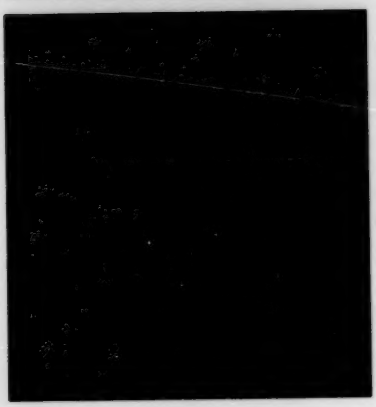


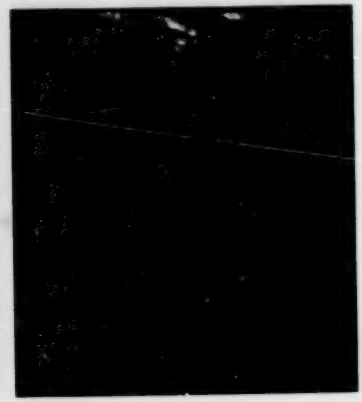
Figure 7. Symptoms of mountain pine beetle attack. Top: Mountain pine beetle initiating attack on a lodgepole pine and pitch response of the tree; centre: Typical pitch tubes caused by mountain pine beetle attack and ring of frass and boring dust around the base of a tree; bottom: Crown symptoms of lodgepole pine attacked by mountain pine beetle.

The first noticeable foliage color change happens in spring of the year following attack. However, white pine will generally fade by autumn in the year it is attacked. Occasionally, if the flight of MPB is early and the summer is hot and dry, crowns will display a chlorotic tinge by fall. The foliage changes from green to yellow-brown to red and then drops off the tree (Fig. 7).

The terms "green", "red" and "grey" attack are based on foliage and stand coloration. Green attack refers to most recently attacked trees containing brood and generally still retaining their green foliage color. Red attack applies to trees with recently faded foliage (red in color) (Fig. 7). Red attack trees may still have brood under the bark or the beetles may have recently emerged. Trees containing no brood, that have been dead for more than a year, and have lost most or all of their foliage are referred to as grey attack. It is extremely useful to distinguish between red and grey attack when doing aerial surveys. Green attack can only be assessed via ground reconnaissance (recces).

Figure 8. Pitch response of lodgepole pine to MPB attack; and adult *Dendroctonus ponderosae* (left) and *Ips pini* (right).





Ground recces are best done in late August and September when beetle presence can be positively identified. Bole symptoms including pitch tubes, frass and boring dust identify fresh attack. The gallery system (Fig. 3) of the beetle is the most reliable indicator of mountain pine beetle activity and can often give critical information as to the vigor of the population. Within days of attack, the sapwood behind each gallery appears dry. This is the first sign of colonization by *Ceratocystis*. Within 2 weeks, the fungi begin to form pigments and infected wood becomes blue stained (Figs. 2 and 5). Staining does not always occur as wood is not always suited to fungal colonization. Main parent galleries are vertical and located primarily in the phloem. Completed galleries are approximately 30 cm long, but occasionally reach up to 90 cm. Larvae mine horizontally to the parent galleries, and by winter to early spring the parent galleries and larval mines have intermingled. Adult beetles are also distinctive and can be identified by morphological characteristics. *D. ponderosae* is recognized by their usually large, stout bodies lacking any elytral declivity (Figs. 3 and 8). Whereas, *Ips pini* are most easily recognized by the concave elytral declivity bearing four spines on each lateral margin (Bright 1976).

II. STRATEGIES AND TACTICS

Long- and short-term strategies must be developed and implemented to successfully manage the mountain pine beetle. In Timber Supply Areas (TSA) and Tree Farm Licenses (TFL) where lodgepole and other pine types are dominant, these strategies should become an integral component of all forest development plans and other higher level plans created for these areas. Mountain pine beetle and other forest health agents play a major role when considering long-term goals and objectives for a land base.

The most effective strategy for managing lodgepole pine and mountain pine beetle is the preventative approach. Long and short term strategies can be addressed in comprehensive forest health plans (FHP). Where FHP have not been written, long-term strategies for dealing with potential MPB populations should be addressed in higher level plans at the forest development planning stage, and followed throughout the life of the stand. Short-term strategies should be addressed at the time of the silviculture prescription (SP). In a comprehensive forest health plan, all forest health concerns are addressed, including root disease, *Armillaria ostoyae*, and lodgepole pine dwarf mistletoe, *Arceuthobium americanum*, which could significantly impact the choice of silviculture system chosen to address MPB. In this way, appropriate strategies and tactics for MPB can be applied. For example, selective, single tree removal of MPB infested stems in an area with a high incidence of *Armillaria* and/or *Arceuthobium* may not be the appropriate treatment, and therefore small to large clearcuts may have to be considered. The balance of this manual addresses the various

strategies and tactics which have been developed to manage the MPB.

Beetle management units (BMUs) are essential for developing management strategies to deal with the mountain pine beetle. They are planning and reporting units for operational beetle management, where a consistent strategy is applied within a discrete area. The strategies chosen for each BMU must be compatible with those of adjacent BMUs. BMUs will provide a basis for evaluating damage to timber, impact on other resources, effectiveness of treatment, and resource allocation and monitoring. BMU strategies should be incorporated into all higher level plans.

BMUs are intended to identify areas where specific beetle management strategies can be applied. Beetle management strategies are broad approaches that have specific objectives. Each strategy has an associated array of applicable tactics or treatments. These treatments are applied to specific infestations or areas within the BMU to achieve the objective of the strategy. BMUs cannot be considered in isolation, as each will have an effect on the beetle situation of its neighbour. Therefor, the strategy selected for a BMU must be compatible with those taken in adjacent units and with the overall integrated resource use plans for the area.

STRATEGIES

There are six strategies that can be used to address mountain pine beetle infestations in a BMU. Selection of the relevant strategy for a particular unit is based on the extent and distribution of beetle infestations in the area. Strategy selection must consider all land use objectives and the expected impact of the beetle in adjacent management areas. The selected strategy will define which treatment combinations are most appropriate and the intensity and frequency of their application. A combination of strategies within a BMU is possible within different sub-units. The six strategies are:

1. Prevention (long-term)
2. Suppression
3. Maintain Low
4. Holding Action
5. Salvage
6. Abandon (no control)

The strategy chosen for a BMU should remain in place for as long as the objectives are being met or until additional resources become available to allow a more aggressive strategy to be implemented. However, situations change from year to year, and therefore strategies must be reassessed on an annual basis.

Strategy selection criteria assume that resource and land use objectives have been met and are given in terms of beetle infestation status and the feasibility of reducing damage. The most technically correct strategy may

not always be selected for a given BMU because other criteria can override technical considerations. For instance, watershed or aesthetic considerations can limit the application of aggressive directed harvesting. Socio-economic forces will also influence the selection of strategies and tactics.

1. Prevention (Long-Term)

The Prevention strategy is applicable to large areas of uninfested or lightly infested timber with a moderate to high hazard rating. Prevention aims at reducing the susceptibility of a particular stand or at reducing its attractiveness to the beetles. The intent of the strategy is to reduce losses through manipulation of forest cover. Long-term management includes plans aimed at age and species mosaics which reduce a stand's susceptibility to the mountain pine beetle (Fig. 9). Total chance development should be practiced. This would include planning and constructing major access routes into moderate and high hazard drainages.

Prevention strategies also indicate that harvesting plans should be based on existing and future hazard and risk criteria. That is, stands with the highest hazard and closest to beetle populations centers (high risk), should be logged or modified on a priority basis. The overall strategy is to remove the susceptible host in an organized manner that will not create extensive and continuous stands of susceptible forest over the next rotation.

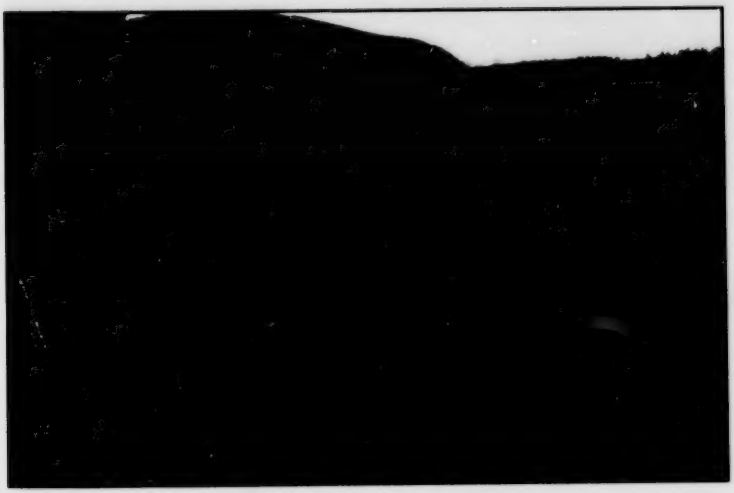


Figure 9. View of non-susceptible (age class 4) lodgepole pine on right and susceptible, older pine on left suitable to be managed under the Prevention strategy.

Prevention could also be considered a tactic to be incorporated into all strategies presented below. One method is to selectively log a stand to a pre-determined spacing that reduces subsequent beetle attack. This procedure is sometimes referred to as beetle proofing a stand and should be considered a holding tactic rather than a silvicultural prescription. This technique is not applicable on a widespread basis and suitable stands must be carefully selected. Criteria for selecting suitable stands are provided in the Tactics section under Beetle Proofing. Stands suitable for such treatment should be identified in the Forest Development Plan.

Suitable tactics for Prevention strategy include the following:

- hazard and risk rating of all pine stands;
- annual aerial overview;
- access planning and development into moderate and high hazard drainages;
- silvicultural treatments, including spacing or thinning, species conversion/mosaics, creation of age-class mosaics;
- extraction/eradication of detected green attack; and
- capturing of infestation data into a Geographic Information System (GIS).

2. SUPPRESSION

Suppression is the most aggressive of the available strategies and is selected when the infestation status is such that aggressive direct control actions are expected to keep an area in a relatively uninfested state. The Suppression strategy demands that each infested polygon be addressed with a single treatment or treatment combination. All possible direct control tactics should be considered and applied where suitable. As well, long-term approaches to reducing future threats to timber or other resources should also be applied. The Suppression strategy is best coupled with the Prevention strategy.

Suppression is the appropriate strategy for lightly infested areas where resources for direct control, or harvesting and milling capacities within the TSA, equal or exceed the amount of infestation (Fig. 10). Access must exist or be imminent. The strategy demands detailed detection and follow-up every year to ensure sanitation of infested stands. Initially, the establishment of such a program may require resources over and above those normally available to a district and may require redirection or some addition to the TSA allowable annual cut (AAC). The intent of Suppression is to reduce the outbreak to a size and distribution that can be handled with normal resources. In most cases, this objective should be achievable within a three year time span.

Figure 10. View of susceptible lodgepole pine showing spot infestations of mountain pine beetle. This area could be managed under the Suppression strategy.

Suitable tactics for Suppression strategy include the following:

- hazard and risk rating of all pine stands;
- annual aerial overview (Forest Service Regional Office);
- annual detailed aerial sketch mapping of all stands with high and moderate hazard at a scale of about 1:30,000 on forest cover maps or photographs (Forest Service District Office and licensees);
- large scale, colour, air photography of high treatment priority areas at a scale of at least 1:12,000;
- intensive ground probing/truthing (recce) of all infested polygons to delineate the extent of infestation and green attack, and to identify harvest options;
- use of all methods of single tree treatments including fall and burn, MSMA, single tree selection, small patch harvesting, etc. within infested polygons;
- aggressive directed harvesting of all infested polygons, including the use of selection cutting regimes in appropriate stands. This will protect remaining site cover from attack, while minimizing opening size and maximizing removal of beetle infested timber;
- semiochemical programs for both single tree and harvest treatment areas; and
- capturing of infestation data into a Geographic Information System (GIS).

This suppression program must be continued until high hazard stands are removed or modified, until the infestation collapses, or until the infestation status exceeds the resources available for a suppression program.

3. Maintain Low

The Maintain Low strategy is applicable in chronically infested stands where the spread of MPB has been reduced to a level that can be dealt with under the normal district program and within the AAC. This also includes areas where the outbreak has collapsed, but where extensive susceptible stands remain. The strategy can be considered a sub-set of Suppression. The intent is to accommodate expected beetle activity in the normal planning process and to deal with newly detected infestations as they arise.

A Maintain Low program will incorporate all relevant activities to prevent rapid increases in the beetle population. Suitable activities include those found in Suppression. The execution of the tactics will be possible with existing resources. It is important that the mountain pine beetle continue to be addressed on a priority basis. Rigorous detection combined with the judicious use of semiochemical baiting and harvest will be common practice. All major access will be in place or is planned in conjunction with hazard rating. Single tree treatments will only be utilized in small inoperable areas of infested timber. A Maintain Low strategy requires high effort and constant vigilance. If attacked trees are missed, they will not immediately present the potential for uncontrollable population expansion. These activities are covered by the Forest Service and licensees as per the responsibility matrix.

Suitable tactics in a Maintain Low program could include the following:

- hazard and risk rating of all pine stands;
- annual aerial overview (Forest Service Regional Office);
- annual detailed aerial sketch mapping of all stands with high and moderate hazard at a scale of about 1:30,000 on forest cover maps or photographs (Forest Service District Office and licensees);
- colour air photography is a useful tool, but optional in this strategy;
- intensive ground probing/truthing (recce) of all infested polygons to delineate the extent of infestation and green attack, and to identify harvest options;
- aggressive directed harvesting of all infested polygons, including the use of selection cutting regimes in appropriate stands to protect remaining site cover in sensitive areas from attack;
- extensive semiochemical programs for both single tree and harvest treatment areas;

- aggressive directed harvesting of all infested polygons, including the use of selection cutting regimes in appropriate stands. This will protect remaining site cover from attack, while minimizing opening size and maximizing removal of beetle infested timber;
- minor use of single tree treatments including fall and burn, MSMA, single tree selection;
- small patch logging within infested polygons combined with other tactics;
- salvage and rehabilitate old infested stands, where feasible; and
- capturing of infestation data into a Geographic Information System (GIS).

A Maintain Low program is a base level program and would continue indefinitely. Resources are expended to keep the beetle population within manageable limits. Overall, the strategy is one of monitoring and mopping up.

4. Holding Action

Holding Action strategy is appropriate in areas with chronic beetle infestations, some of which are too large to deal with using single tree treatments or where access is poorly developed for directed harvesting. Holding Action would be recommended for a BMU or a sub-unit where aggressive suppression would be appropriate but the unit has a lower priority than other areas. It could also be used where resources are inadequate to deal with all infestations.

The intent of a Holding Action strategy is to maintain an existing outbreak in an area at a relatively static level. It is a delaying strategy until adequate resources are available, allowing for more aggressive management. Typically, spot baiting, with occasional grid baiting is employed to prevent or reduce insect dispersal and infestation spread.

Spot or grid baiting of specific stands should be repeated for a maximum of two years. Limited single tree treatments and harvesting where feasible must be included in a Holding Action strategy.

Suitable tactics for Holding Action strategy include the following:

- hazard and risk rating of all pine stands;
- annual aerial overview(Forest Service Regional Office);;
- annual detailed aerial sketch mapping of all stands with high and moderate hazard at a scale of about 1:30,000 on forest cover maps or photographs (Forest Service District Office and licensees);
- access development plans should be formulated based on hazard and infestation patterns;
- intensive ground probing/truthing (recce) of all new infested polygons;

- use selection cutting regimes as a holding action to protect remaining site cover in sensitive areas from attack, until the stand can be treated with a more appropriate silviculture system;
- use of all single tree treatments including fall and burn, MSMA, single tree selection, small patch logging, etc. in infested polygons;
- semiochemical programs for both single tree and harvest treatment areas;
- spot or grid baiting programs in infested polygons where single tree treatment or single tree harvesting is not possible; and
- capturing of infestation data into a Geographic Information System (GIS).

A Holding Action is a temporary strategy and should not be maintained indefinitely. There must be a clear time horizon for access development to permit more aggressive directed harvesting and for the application of direct control options. Depending on the hazard and risk of the area, the infestations should be dealt with in two to three years. Holding Action activity must be maintained annually until the strategy is revised.

5. SALVAGE

A Salvage strategy is appropriate in areas which have extensive outbreaks (past, or ongoing) covering a large proportion of the available susceptible stands and where access is planned or possible within a five year period. It is also applicable in areas where the required control actions exceed the available resources. Infested areas will have relatively high proportions of red and grey attack, indicating that the outbreak has been ongoing for several years. Smaller, moderate or low hazard stands are commonly infested. The intent of this strategy is to delineate those areas where management efforts would be ineffective in substantially reducing the beetle population and subsequent levels of damage.

A Salvage strategy would be implemented when sufficient harvesting capacity was available and all other high priority areas for beetle control were being adequately addressed. Timber in these areas can then be salvaged and the sites returned to production. Long-term silviculture strategies would be implemented at this point.

Suitable tactics under the Salvage strategy include the following:

- annual overview sketch mapping to monitor general spread of beetle or area to be salvaged;
- limited single tree treatment in the stand periphery to limit spread to other areas which may have different, more aggressive strategies, such as Maintain Low or Suppression;
- development of criteria to establish salvage priorities based on levels of attack and rate of lumber quality degrade;

- salvage of timber as harvest capacity permits while not detracting from management efforts in other BMUs;
- limited semiochemical baiting in blocks directly adjacent to areas having more aggressive BMU strategies in place. This could restrict dispersal of beetles out of the area and into active control zones (only upon consultation with the Regional Entomologist); and
- capturing of infestation data into a Geographic Information System (GIS).

Figure 11. View of a drainage in the south Okanagan, within a salvage BMU, showing past and current mountain pine beetle attack, and salvage harvest blocks.

6. ABANDON (no control)

The intent of the Abandon strategy is to identify areas where management efforts would be ineffective in substantially reducing the beetle population and subsequent levels of damage, where there is no short-term (<5 years) possibility of salvaging dead timber, or where there are other management objectives that preclude addressing the beetle population. This may be due to management issues such as wilderness or parks, biodiversity objectives or because access cannot be put in place before substantial merchantable degradation of the dead material occurs.

Areas warranting this approach may be similar to those selected for the Salvage option, however, access is either poor or non-existent and not planned within a five year time frame. Other cases for an Abandon option may include infestations in parks or wilderness areas where the beetle is unlikely to spread and affect commercial timber or other resource values. These areas will be delineated upon consultation with other resource agencies.

Other than in special management circumstances, such as noted above, the Abandon strategy is a "last resort" and indicates that a control/management program has failed or was not implemented at an early stage of the outbreak. In the determination of a TSA's allowable annual cut, non-recoverable losses must be accepted; the loss must be evaluated; and, the allowable annual cut may have to be reduced accordingly.

Suitable tactics under the Abandon strategy include:

- annual overview sketch mapping to monitor general spread of beetle or area killed;
- a re-analysis when the outbreak is over and development of a long-term management plan for the area;
- development of access plans depending on resource objectives;
- development of criteria to establish salvage priorities based on levels of attack and rate of quality degrade;
- salvage of timber as resource objectives, wood quality, and harvest capacity permits, while not detracting from management efforts in other BMUs;
- rehabilitation of areas designated for timber production; and
- capturing of infestation data into a Geographic Information System (GIS).

TACTICS

Tactics are equivalent to treatments and are applied to specific areas or infestations within a BMU. The appropriate combination of tactics must be selected for each strategy to accomplish the stated objectives. Rarely will a single treatment be sufficient to deal with a particular infestation. Normally, a combination of treatments will be necessary. Further, most treatments will have to be repeated each year that the strategy remains in place. Unless the nature of the forest is changed, the susceptibility, and often the risk of subsequent infestation, will be similar from year to year.

Relevant tactics are described in this section. However, new treatments are continually being developed and applications being refined. The Regional Entomologist will be able to provide local variations in application and to advise on new developments.

1. SURVEY/ASSESSMENT

General categories of infestation intensity can be determined from aerial sketch mapping surveys. These evaluations can be used to prioritize stands for further ground truthing or treatment. Precise measures of intensity are not possible from general aerial observation, however broad categories can be judged with some confidence. In all cases in aerial surveys, assessments are made on the basis of visible red attacked trees or fading, current year attack (green attack). The level of green attack is then verified by ground reconnaissance or probes.

Depending on attack history and host abundance, results of aerial surveys can be scaled to fit local situations. Any detected green attack should be treated seriously and be dealt with expediently. Aerial survey

determinations can be used to identify areas clearly amenable to the Salvage strategy and to identify areas needing ground surveys. In all cases, actual levels of attack are necessary for the prioritization process. Ground survey information should be collected and calculated to the nearest percent value (not range of values). Priorities for sanitation harvesting should be based on ground survey information. In addition, ground surveys are the only way to positively confirm the causal agent of the visible damage. Spot infestations can be set aside for single tree treatment. When using green attack levels as the basis for prioritizing areas for treatment, i.e. harvesting, always compare levels of attack among equal land base units.

There are two types of aerial surveys: overview and detailed. These surveys are recommended as data collecting techniques for landscape level surveying. The two techniques include the following:

A. Overview flights

Overview sketch mapping is usually done in a fixed-wing aircraft at a scale of 1:100,000 or 1: 250,000. This level of survey is conducted annually by the six regions of the B.C. Forest Service. The purpose of overview surveys is to capture all disease and insect conditions in the forest, not just bark beetle infestations. Overview surveys are not sufficiently detailed for operational planning when bark beetle levels are high, but they are useful for annual monitoring of uninfested areas to detect the first signs of insect activity. Overview sketch mapping is necessary for areas with very high beetle activity that are not suitable for management action, such as parks, protected areas and inoperable ground. General overviews are also very important in maintaining historical records, which can be used for research purposes, or to develop further management tactics.

B. Detailed surveys

Detailed sketch mapping is typically conducted in rotary-winged aircraft, on a forest cover map at a scale of about 1:30,000 (Fig. 12). Detailed survey flights are done over all operational areas, and all infested spots as indicated by red-tops or fading foliage, are drawn to scale on a map. An estimate of infestation intensity should also be made for each attack polygon noted (Table 2). GPS (geographical positioning system) coordinates can be taken at key attack polygons. This detailed survey, coupled with hazard rating, forms the basis for allocating management resources and responsibilities.

Table 2. Attack intensity classes for mapping mountain pine beetle during aerial surveys.

Attack intensity	Description of attack intensity
x	For single trees, or polygons estimate the number of red or faded trees
Light	0-5% of total stems affected
Moderate	6-15% of total stems affected
Heavy	16-25% of total stems affected

C. Aerial photography

Aerial photography should primarily be done in areas where intensive control efforts are planned. Such photography should be done at a scale no smaller than 1:12,000. The photographs are then used to plan ground surveys and the allocation of treatments such as single tree, selection harvest, and clearcut harvest.

The use of oblique, 35 mm, aerial photographs is useful in locating infestation spots on the ground after aerial detection flights. These photos are taken at as large a scale as possible and should include prominent landmarks to facilitate future access by ground. A GPS coordinate should be taken with each set of photographs.

D. Ground detection

Ground detection is necessary to confirm information gathered from detailed sketch mapping. There are two types of ground surveys: walkthroughs (recces) or probes. Ground surveys obtain data on levels of current (green) attack and the amount of remaining susceptible host material. Information gathered from ground surveys is used to delineate infested areas and make decisions as to the most appropriate treatments.

Walkthroughs are preliminary, non-systematic, ground reconnaissance surveys done prior to probes. They are thorough ground checks of susceptible stand types within an area that is generally broken down into 10 ha units. Attack levels (current and past), species composition and stand characteristics, merchantability, operability and treatment prescriptions are assessed. Recces locate and delineate spatially discrete pockets of infestation. Walkthroughs consider the values at risk, such as watershed, fisheries, wildlife habitat and other environmental criteria, and are usually the first survey done in a stand. Recces may be all that are required for areas showing new infestations (spots). In areas with higher or more scattered levels of green attack, recces may indicate the need for a more detailed survey or probe (Table 3).

Probes are systematic, strip-type surveys which continue through a stand until no further infestation is noted or until there is a timber type change. Probes collect more detailed stand and infestation data (Table 3). Minimum data that must be collected and tallied for each infested polygon are listed below:

- location of probe/walkthrough lines and intensity of attack should be drawn on forest cover maps of appropriate scale;
- the size of the infested polygon surveyed;
- stage(s) of beetles under the bark (egg/larva/pupa/adult); ratio of different stages; and, relative brood success (check on average 1 green attack tree per 100 m surveyed);
- percentage of various attack categories;
- rate of spread (as indicated by green to red ratios);
- amount of susceptible host remaining;
- average diameter of susceptible stand remaining;

- total stems per hectare;
- an estimate of the operability;
- access;
- potential other resource use issues or constraints; and
- other forest health issues that may influence the final prescription.

Table 3. Recommended ground survey method and intensity based on infestation ratings gathered from aerial surveys.

Aerial Survey Rating	Recommended Ground Survey Method
≤5% current attack	Detailed (100%) walkthrough of area to delineate green attack
6-15% current attack	Full probe of area, unless entire polygon scheduled for harvest
16% and greater current attack	Walkthrough of area to verify status of insect population

In all cases, probes and walkthroughs should tally all stems ≥12.5 cm dbh, and occasionally all stems ≥7.5 cm dbh.

A probe is an intensive survey that determines the level of MPB infestation in a stand. Whether or not a probe should be conducted is dependent upon the strategy in place for the area and the proposed treatments. If the infested polygon is contained within a proposed cutblock, then a walkthough would be sufficient to delineate the boundary of the beetle population.

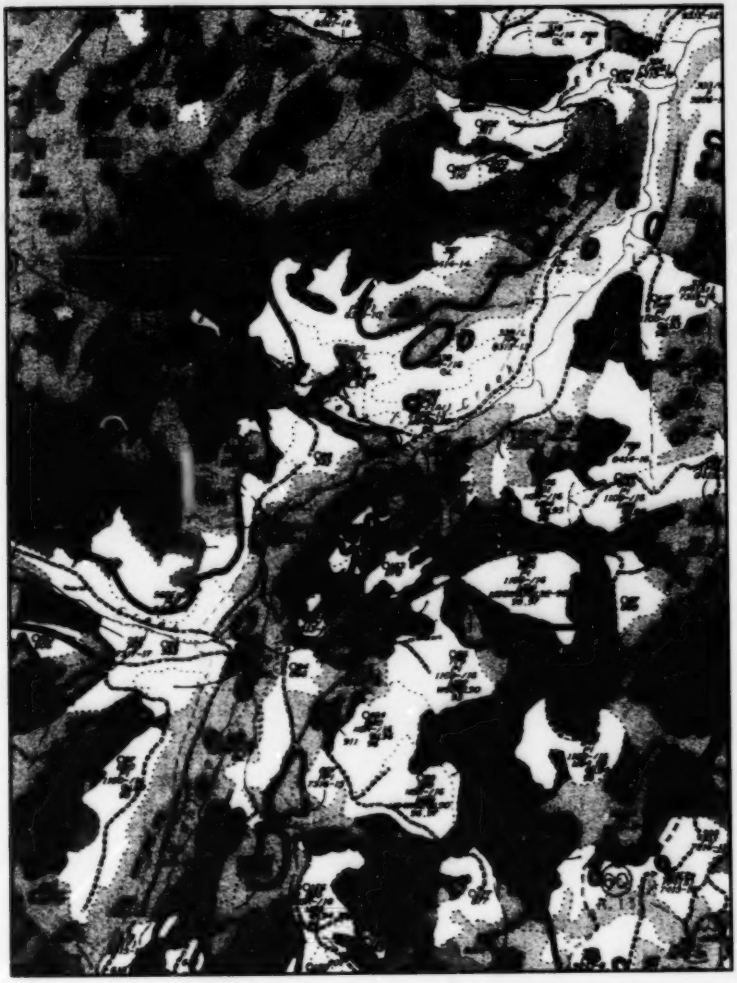
To conduct a probe, a baseline is established within a beetle-infested area and survey lines are run perpendicular to the baseline at 50 to 200 m intervals (or at desired intensity). Plots are continuous and strips will run until the edge of the survey area is reached or a reasonable distance beyond the last red or green attacked tree, whichever comes first. All susceptible pine species measuring >12.5 cm dbh, and other commercial species measuring >17.5 cm dbh will be tallied in a 5 m wide strip. Other forest health factors and any features pertinent to harvesting such as creeks, roads, marshes, and cutblock openings should be noted.

Beetle-attacked trees off the probe line should be noted as well. A surveyor should recce these areas.

E. Hazard rating

Hazard rating of stands is intended to identify those stands that are highly susceptible to attack by mountain pine beetle (Fig. 12). Once all pine stands in an area have been rated, resources can be directed toward those stands with the highest hazard so that losses can be minimized. Hazard rating considers stand age, host basal area, stand density, and elevation; and, identifies stands where high volume losses can be expected should a beetle outbreak arise. These procedures should be applied to all pine stands in a BMU as a basis for allocating management resources.

Figure 12. Two maps showing a section of forest cover map (1:30,000) in the Whipsaw Creek drainage: the first map shows the susceptibility of stands to mountain pine beetle infestation; and, the second map shows detailed mapping of mountain pine beetle activity (red lines) overlaid on the short-term risk to mountain pine beetle. The susceptibility and risk classes are shaded in green, with: white = nil; light green = low; medium green = moderate; and, dark green = high.



Hazard rating of pine stands is intended to identify those stands that are highly susceptible to attack by the mountain pine beetle. There are two components in establishing a stand risk index (SRI). The first, a hazard or Stand Susceptibility Index (SSI), is a measure of the degree to which various characteristics of a stand make it vulnerable to MPB attack. The second, Beetle Pressure Index (BPI), is an indicator of the magnitude and proximity of a MPB population to a susceptible stand. Risk is a combination of these two elements (Shore and Safranyik 1990).

The Stand Susceptibility Index is calculated based upon several variables:

1. Average age of dominant and co-dominant live pine >15 cm dbh.
2. Average basal area/ha of all live pine >15 cm dbh.
3. Average basal area/ha of all live commercial species for trees >7.5 cm dbh.
4. Average number of stems/ha (all species) of the stand >7.5 cm dbh.
5. Elevation-Latitude-Longitude of the stand.

One can then calculate the susceptible pine basal area using the following equation:

$$\frac{\text{(Average basal area/ha of pine >15 cm)}}{\text{(Basal area/ha of all species >7.5 cm)}} \times 100$$

Hazard rating for mountain pine beetle requires inventory and location information. Data should be collected from prism plots in the field in order to calculate the hazard index. Ten plots spaced at 100 m intervals will suffice if the stand is fairly uniform. However, if the stand is quite variable between plots, then a minimum of 20 plots should be sampled. The following must be recorded:

- BAF (basal area factor) of the prism used.
- Tree species and dbh for each "in" tree >7.5 cm dbh measured in the plot.
- Age of the closest dominant or co-dominant pine tree to plot centre from an increment core taken at breast height.
- Stand elevation determined with an altimeter.

When the data are available, the hazard index is calculated using the formula:

$$\mathbf{HAZARD = P * A * D * L}$$

where P = percent of susceptible pine basal area
A = age factor
D = density factor
L = location factor.

Methods for determining these factors are provided below.

P = % of susceptible pine basal area

$$P = \frac{\text{(average basal area / ha } \geq 15\text{cm dbh)}}{\text{(average basal area / ha all species } \geq 7.5\text{cm dbh)}} \times 100$$

A = age factor for mountain pine beetle hazard rating.

Age (years)	Factor
≤60	0.1
61 - 80	0.6
≥81	1.0

D = density factor for mountain pine beetle hazard rating

Density[a] (sph)	Factor
≤250	0.1
251 - 750	0.5
751 - 1500	1.0
1501 - 2000	0.8
2001 - 2500	0.5
>2500	0.1

[a] stems per ha of all species ≥7.5 cm dbh

L = location factor for mountain pine beetle hazard rating is determined by calculating Y:

Y = (24.4 X longitude) - (121.9 X latitude) - (elevation (m)) + (4545.1)

Y	Factor
>0	1.0
0 to -500	0.7
<-500	0.3

Stands that are leading in lodgepole pine type, aged sixty years and older and that have the elevation, latitude and longitude code equal to high, should be considered a high priority for hazard rating and management. Contact the Regional Entomologist for further information on hazard and risk rating and availability of existing maps.

F. Risk rating

Risk rating estimates the probability of an outbreak arising and is dependent on the proximity of a particular stand to an existing beetle population source (Fig. 12). The risk of attack in any area can be determined by overlaying detailed sketch mapping and available ground detection results, on a forest cover map that has been coded for hazard. This is most efficiently done using a GIS.

Mountain pine beetle risk is a dynamic factor and is prone to change suddenly if climate conditions fluctuate or if there is an immigration of beetles from another area. Risk is related to the size and proximity of a beetle population affecting the stand being assessed. To arrive at a risk rating, the size of infestation and the distance of the infestation from the stand being assessed must be measured. Because beetle risk is a variable factor, it should be calculated annually or biannually.

Once both risk and hazard are known for stands within a planning area, individual stands can be ranked for survey, treatment, or other action. The resultant priority listing for actions can then be determined using Table 4.

Table 4. Determining priority for action based on stand hazard and associated risk.

	HAZARD		
RISK	**Low**	**Moderate**	**High**
Low (> 1 km to MPB)	Very Low	Low	Moderate
Moderate (<1 km to MPB)	Low	Moderate	High
High (within MPB attack)	Low	High	Very High

The most important use of hazard and risk rating is in the planning and development phases of forest management. Where beetle infestations exist, the risk is high and the hazard is determined by the stand parameters. This will provide information as to the potential for spread.

G. Population Prediction

Two types of surveys can be conducted annually in areas of infestation to determine beetle population trends. MPB population trends can be estimated by calculating the ratio of currently attacked trees to one-year-old attacked trees. A ratio of >1 indicates an increasing population; a ratio of <1 indicates a declining population. The estimate should be determined with the aid of bark sampling in the early spring, when potential new brood can be compared to the initial attacking population.

The second type of population prediction tool uses the population trend ratio (r). This ratio may be calculated for each sampled tree as follows:

$$\text{"r"} = \frac{a + b}{c}$$

where a = number of eggs and larvae
b = number of pupae and adults
c = number of galleries originating within sample area

A recommended sample area is a 20 cm by 20 cm square of bark. Then, for each stand, the average (R) is calculated thus:

$$\text{"R"} = \frac{\sum (r) \text{ from all sampled trees}}{\text{number of trees sampled}}$$

Overwinter mortality estimates using population trend ratios (r-value) may be conducted in the spring. The following equation illustrates how overwintering mortality is determined.

$$\frac{\text{R fall - R spring x 100}}{\text{R fall}}$$

These results are supplemented by fall surveys which determine current attack and help estimate volume losses and infestation trends. The number of entrance holes on the bark sample represents the number of attacking female beetles. Bark sampling should be done in the spring following attack to account for overwinter mortality and losses to parasites and predators.

Once the "R" value has been calculated, consult the table below to interpret MPB population status. "R" values will indicate whether beetle populations are static, increasing or decreasing in an affected area.

"R" value	**Population Trend**
≤ 2.5	decreasing
2.6 - 4.0	static
≥ 4.0	increasing

2. HARVESTING

A. Sanitation

Sanitation harvesting is directed at reducing beetle population levels by logging. Priorities for harvest are determined from aerial and ground surveys regarding levels of green and red attack. Stands with the highest levels of new attack and with a high potential for continued spread should receive the highest priority for removal. Sanitation harvesting includes all harvesting methods such as clearcutting, shelterwood, and selective cuts. Long-term preventive strategies should be implemented at the time of harvest to create non-susceptible or less susceptible stands in the next rotation.

B. Salvage

Salvage harvesting is directed at the removal and processing of dead timber before the wood has degraded below merchantability. Priorities for salvage cutting are determined on the basis of the levels of old attack in the stand, and the age and quality of the timber. Salvage cutting does not reduce further beetle damage. Salvaging dead timber returns the site to forest production and anticipated resource values should be considered when developing the prescription. Long-term preventive approaches should be implemented at the time of subsequent stand establishment.

C. High hazard host removal

Removing uninfested, high hazard host is a preventative measure. Susceptible host is removed on a priority basis thus preventing the onset or spread of an attack. Harvesting of such uninfested wood is appropriate in either uninfested or lightly infested management units, but should be deferred if the management objectives for the area are to reduce beetle damage. Hazard rating and risk rating systems, integrated with the landscape level planning process and biodiversity objectives will identify landscape units where high hazard host removal is an option. This tactic is mostly applicable to a Maintain Low or Prevention strategy, but can be considered in a Suppression strategy if harvesting capacity is in excess of that required to deal with other active infestations. High hazard host removal harvesting does not necessarily mean clearcutting. Other harvesting methods may also be appropriate.

D. Harvest priority rating system

It is necessary to establish a method to determine stand harvest priorities so that the heaviest beetle concentrations can be removed first. This is especially important when harvest or milling capacity is insufficient to address all beetle infestations. Harvest priorities for beetle control will range from high where beetles are active and the risk to adjacent stands is

high, to low in the case of stands deemed as salvage. Criteria to be used for determining harvest priorities include:

- level of current attack;
- rate of increase of the beetle population;
- risk to adjacent stands or timber remaining in the affected stand;
- amount and size of susceptible timber remaining;
- operability;
- merchantability; and
- available access.

3. Single Tree Treatment

The success of single tree treatments is dependent upon the correct timing and method of application. Application of single tree treatments is most successful in low or moderate hazard ecosystems, when beetle populations are still relatively low. In high hazard ecosystems, single tree treatments are less effective except when used in conjunction with other harvesting or suppression tactics, or as a "mop-up" tactic. Thoroughness is also required to ensure that a substantial portion of the beetle population is removed in a single tree program. Detailed detection surveys are necessary to ensure that complete treatment is achieved in an affected stand. All treatments require periodic spot checks to ensure and measure efficacy. Monitoring and possible re-treatments are necessary activities.

A. Small patch/single tree selection

Small patch and single tree extraction is the preferred single tree treatment method. Small infested patches, preferably less than 1 ha in size, but as large as 2 ha, may be cut, removed and processed. In a given geographic area containing low level, scattered or spot attacks, individual infested trees can be removed and utilized. This is often referred to as the "hunting license" approach. This small scale, focused harvesting option is one of the most effective treatments in Prevention, Suppression and Maintain Low BMUs having low or moderate hazard.

B. MSMA (monosodium methane arsenate)

MSMA is an organic arsenical pesticide that can be used in similar circumstances as the fall and burn tactic. The major constraint is that trees selected for treatment with MSMA must be treated within three to four weeks of initial attack by the mountain pine beetle (Fig. 13). At the base of the tree, using a sharp axe, make a continuous shallow axe frill around the total circumference of the tree. The axe cut should penetrate through the bark into the first ring of sapwood. MSMA (70% active ingredient) is injected into the frill at the rate of 1 ml per 2.5 cm of circumference (Fig. 14).

Figure 13. Diagram showing stage of mountain pine beetle gallery construction that is optimum for treating with MSMA. If treated later than this stage, efficacy of MSMA treatment drops off drastically.

Areas designated for MSMA treatment may be considered for pre-treatment spot baiting, for 1 year only. A second year of MSMA treatment in an area should be a mop-up effort and if significant attack is still present, then alternative treatments should be considered. MSMA treatments in a district or TSA. should be planned as a 2-entry system, starting at the lowest elevation sites in late July (or when beetle attacks are noticed) and moving to higher elevation sites as the season and beetle flight progresses. A second entry into stands approximately 3 weeks following the first treatment date will ensure that any subsequent attack or trees missed in the first entry are treated. Once a tree has been treated with MSMA, no subsequent attack will occur on that tree.

A Pesticide Use Permit must be obtained prior to conducting an MSMA program. There are certain standard restrictions in Pesticide Use Permits on the use of MSMA. These could include:

1. A 10 m pesticide-free zone shall be maintained along all water bodies.
2. The boundaries of the pesticide-free zones or their buffer zones shall be

Application rate (kg a.i./ha) = $\frac{\text{No. of trees to be treated x (kg a.i./tree)}}{\text{Treatment area (ha)}}$

Treatment area (ha) = $\frac{\text{No. of trees to be treated}}{\text{Average stocking density}}$

Application rate = 1 ml of total volume (MSMA formulation) per 2.54 cm of bark circumference.

Circumference = 3.14 x (tree diameter)

Application rate per tree = $\frac{\text{(cm total circumference at injection point)}}{\text{2.54 cm}}$

➡ x ml total volume per tree
➡ x ml x 0.00032 kg a.i./ml (full strength MSMA)
➡ gives kg a.i./tree

Treatment area (ha) = $\frac{\text{assume 100 trees to be treated}}{\text{assume 300 stems per ha}}$

➡ 0.33 ha

Application rate (kg a.i./ha)= 100 x (*amount* kg a.i./tree)/0.33 ha
➡ a.i. per ha

Figure 14. Form used to calculate MSMA quantities for post-attack injection against mountain pine beetle.

clearly marked before any pesticide application.

3. No pesticide shall be applied within 30 m of domestic water intake or wells.
4. All personnel involved in the project shall be notified of the terms and conditions of the permit.
5. MSMA shall be applied at the rate of approximately 10.2-10.4 kg a.i. per ha.
6. Every one of four MSMA applicators must hold a valid Pesticide Applicator's License. This may change shortly to: every applicator must hold a valid Pesticide Applicator's License.

Records must be kept that document the number of trees treated in each area and information on the stage of beetle development (Fig. 13). This information is used to track efficacy and use of the MSMA treatment and must be submitted annually to the Ministry of Environment, Lands and Parks, Pesticide Management Program.

LOCATION: _____

DATE _____

STAGE OF MPB ATTACK

Average length of parent gallery: _____ cm

Eggs laid: yes no

Larval mining present: yes no

Average length of larval mines: _____ cm

DENSITY OF ATTACK
(no. galleries/20 cm^2) _____ cm

NO OF TREES TREATED IN AREA: _____

Figure 15. Example of MSMA-treatment data form.

C. Fall and burn

This direct treatment is used to eradicate small spots or patches of infested trees in lightly infested areas; scattered attack on the periphery of larger infestations; and in areas where other resource constraints limit other treatment options (e.g. creek side treatments). Fall and burn may be used to sanitize stands. Infested trees with red or green crowns that contain live beetle broods should be felled. The infested portions of the trees should then be bucked, piled and burned, ensuring that all infested bark area is well burned. Thorough surveys in affected stands are important to ensure that infested trees are not missed. Areas must be re-surveyed and likely re-treated in subsequent years. Baits placed subsequent to treatment and prior to the next beetle flight period will assist in ensuring thoroughness in follow-up years. This treatment can be applied throughout the year in accordance with fire prevention regulations.

D. Preventative insecticide

This is a preventive treatment that will protect high value trees from attack. Treatment is required annually. Preventative sprays are applicable in campsites, urban areas, and in other highly specialized circumstances. This

treatment is not suitable for stand protection in a forest environment. The insecticides most often used for this treatment are Sevin® and Dursban®. They can be used as preventative, pre-attack sprays, or post-attack , pre-emergence sprays. For pre-attack treatment, spray is applied in late May to early June. Treat trunks from ground level up to until trunk diameter is <12.5 cm. For post-attack, pre-emergence treatment (used to kill emerging adults and protect surrounding trees), apply spray in the period mid-June to mid-July, covering the entire portion of the trunk attacked by MPB. Apply sprays as per Pesticide Labels and directions.

E. Debarking

As an alternative to fall and burn or MSMA treatments, trees may be felled and debarked. This treatment should be done from September through May and is not applicable once the beetle brood have passed the pupal stage.

F. Helicopter logging

Helicopter logging can be used to extract small infested patches where there is no ready access. The cost of helicopter removal can be totally or partially offset by sale of the timber, thereby making the actual cost of the technique approximately the same or less than other direct treatments.

4. Baiting Techniques

The use of aggregating semiochemicals baits has greatly facilitated efforts to reduce losses caused by the mountain pine beetle. Baiting stands prior to harvest, or other treatments, will reduce the spread of local populations of beetles, thereby reducing the size of sanitation cutblocks and greatly reducing the time and effort required to detect and delineate infested portions of stands.

A. Contain and concentrate

The use of baits must be regarded as a temporary holding technique that can concentrate a local beetle population in the general area where baits are placed. **The use of baits must always be followed by actions to remove or eradicate the concentrated beetle populations.** Baits will intensify bark beetle populations and losses will increase if bait use is not followed by remedial action such as harvesting, single tree removal, or treatment with MSMA. It is recommended that infested stands receive only two consecutive years of baiting, and treatment of baited stands must be implemented within that two year period. **It is strongly recommended not to place any baits in inaccessible areas where beetle populations are negligible.**

There are two options for placing baits in an affected stand: Spot baiting and grid baiting. In the past, some users have baited only on the perimeter

of affected blocks, rather than grid or spot baiting within the designated blocks. This practice is not efficient. Perimeter-only-baiting can lead to enlargement of existing openings by aggregating beetle attack on the edges of proposed blocks rather than in the central portion and does not necessarily reduce beetle populations. It is recommended to bait in nearby blocks that are planned for harvesting or to do sweeps of block perimeters treating new attacks with MSMA or extracting infested trees.

B. Monitoring

Baits can be used to monitor the timing and duration of the beetle flight. It is necessary to monitor for the correct timing of MSMA application and to determine the period when hauling restrictions may be necessary. Monitoring with semio-chemicals may be done as follows: use baited Lindgren funnel traps in several accessible locations and monitor insect catches on a regular basis (weekly from mid-July until end of peak flight). Initial, peak and final flight dates can be determined using this method. Avoid spillover attack by frequent monitoring and have a contingency plan for any spillover attack which occurs (e.g. MSMA).

Maximum trap catches occur when temperatures exceed the 20°C necessary for maximum beetle flight (Lindgren 1992). Variables such as aspect and elevation may influence trap catch. However, there is some indication that beetle flight occurs slightly earlier at lower elevations. For proper timing and coordination of an MSMA program, knowledge of initial and peak flight dates is very important.

C. Follow-up on single tree treatments

Baits placed in single tree treatment areas will localize any residual beetles and facilitate subsequent treatments. In effect, the use of baits will pre-select the sites for treatments such as MSMA, where timing of application is crucial for success. Single tree treatments are not always 100% successful, therefore some post-treatment spot baiting may be necessary.

D. Stand and infestation parameters

A number of factors must be considered when selecting a bait use strategy in a particular area. The overriding factor is the landscape level plan and the management objectives outlined for the area in question. Other factors include:

1. **Current infestation status in a drainage:** For example, if a drainage has been green and healthy for years and suddenly incurs a scattered (1-2% or greater) attack in a one year period, this is a critical situation and should be dealt with immediately.
2. **Risk:** Refers to proximity to the nearest active infestation within a drainage.

3. **Area affected:** The size and volume under scattered attack by MPB must be determined. Infested area refers to discrete pockets of attack within affected drainages.
4. **Spatial distribution of currently attacked trees within a candidate stand:** Locate beetle attack within a stand and describe the spatial distribution of the attack as either clumped, random, or regular.
5. **Hazard class of residual stand:** Hazard depends on several parameters such as tree age, diameter, phloem thickness, stand elevation, aspect, and geographic location.
6. **Infestation status and hazard class of adjacent stands.**
7. **Outbreak status:** Note whether the infestation is increasing or decreasing.

Baiting Techniques Selection

Baiting techniques in outbreak situations are dependent upon the stage of the outbreak: i.e. early *vs.* late. The outbreak stage can be defined by the relative number of green/red/grey attacked stems in a stand compared to the remaining number of potential and susceptible hosts. High numbers of green attack with low to moderate levels of red and grey attack and an abundant number of hosts remaining, indicate an early to mid-stage of an outbreak. Strategies that are appropriate in these circumstances include Suppression or Maintain Low which recommend an aggressive use of baiting with associated harvest and single tree treatments. Landscape level management objectives will guide the level and technique of harvesting.

High numbers of red and grey attacked stems in relation to green attack with decreasing numbers of potential hosts available to MPB, indicate a mid- to late-stage of an outbreak cycle. Strategies that are appropriate in these circumstances include Holding or Salvage. Grid baiting is recommended to limit beetle dispersal and restrict the size of sanitation cutblocks. In a salvage strategy, no baiting is recommended when there are insufficient hosts remaining to absorb the potential beetle flight.

The decision of whether or not to bait in an outbreak area should be based on the number and quality of remaining hosts in the infested stand. The stand should be assessed to determine the stage of the outbreak cycle. The area of heaviest infestation should be delineated to facilitate extraction prior to the next beetle flight. The remaining infestation should be baited to contain and concentrate post-flight for extraction in the subsequent year.

Right-of-way baiting

In right-of-way baiting, baits are placed at 25 m intervals along the proposed right-of-way one year prior to harvesting. If the right-of-way is not harvested as scheduled, all attacked trees must be removed or beetles destroyed prior to beetle emergence. As well, recces must be done adjacent to the right-of way and any further beetle attack must also be

removed. In areas with high hazard pine types, and no evidence of MPB attack, right-of-way baiting is not recommended.

General guidelines for baiting patterns in a variety of circumstances are presented below.

1. Uninfested drainages
Uninfested drainages of low to moderate risk fall into the Prevention or Suppression strategies. The following baiting techniques pertain to areas which are remote from, and show no signs of beetle activity.

a) In areas with large expanses of mature, high hazard lodgepole pine which are geographically remote but with access routes in place, as well as remote from the nearest known MPB outbreak (low risk); baiting is not recommended. Some baits may be placed to evaluate the local population status but should not be used without consultation with the Regional Entomologist and must be followed up by planned treatment of baited sites.

b) In areas which are geographically remote, inaccessible, have mature high hazard lodgepole pine stands, and are also remote from the nearest MPB outbreak, **baiting is NOT recommended.** The only exceptions to this rule would be in very special circumstances with the approval of the Regional Entomologist.

2. Uninfested, semi-accessible stands
Under certain circumstances, baiting may be recommended in high-hazard, uninfested, semi-accessible, lodgepole pine stands. Baiting may be acceptable in the scenarios outlined below:

a) If a high hazard drainage is greater than 1 km from a MPB infestation, it is considered moderate risk. In this situation, do not bait without consultation with the Regional Entomologist.

b) If a high hazard drainage is within 1 km of a MPB infestation, it is considered high risk. Baiting is recommended for 1 year **(and one year only)** prior to harvest, with the guarantee that the block will be extracted within that year. Grid baiting and other baiting methods may be deployed depending on site specific information.

3. "Salt & pepper" attack
Mountain pine beetle infestation exists in some or all stands in a drainage. Baiting techniques for areas showing scattered MPB attack are dependent upon the criteria listed in Baiting Techniques (4D). Continued annual surveillance is critical to assessing bark beetle population dynamics and must be compared on a yearly basis. New attack in an area, drainage or stand will thus be identified.

Three scenarios of scattered MPB attack are described below with

recommended baiting techniques. In general, spot and patch infestations of MPB should be spot baited to hold the infestation within the affected stand while still at relatively low infestation levels.

a) **Drainage mostly uninfested** (Suppression or Maintain Low Strategy)

   i) **Isolated spot infestations:** Spot baiting to restrict beetle dispersal; limited grid baiting only in infested portions of stands. This must be done in conjunction with an application for a Cutting Permit.

   ii) **Some occurrences of patch infestation:** Spot baiting of any discrete clumps of infestation; grid baiting of patches with assured harvest. Any particular stand should be baited for 2 consecutive years at the most, if harvest cannot be done in the first year.

b) **Drainage generally infested** (Maintain Low or Holding Action Strategy)

   i) **Many stands affected with spot or patch infestations:** Sanitation harvesting with small block extraction, where possible, utilizing grid baiting. To maximize the sanitation effect of harvesting, ensure that grid baiting is done in smaller discrete blocks that address concentrated areas of infestation within affected stands. Spot bait to hold areas with lower levels of infestation for harvest within one year.

5. Hauling Restrictions

Instances have occurred where beetles have been transported during the emergence period and have subsequently started infestations in previously uninfested areas. The danger is greatest when loaded log carriers stop for some period of time. It is unlikely that many beetles escape while loads are in motion.

Hauling restrictions may be necessary if points of destination are located in uninfested drainages containing substantial amounts of high hazard timber. If points of destination are located in these high hazard areas, hauling may continue if there is a stipulation that logs be milled within a 24 hour period. Follow-up monitoring must be done after beetle flight, to locate any green attack resulting from hauling and milling during the flight period. Such restrictions are necessary for as long as the emergence and flight period lasts. For scheduling purposes, select a start date in advance of the flight period, e.g. July 15th. Removal of the restriction is based on Lindgren funnel trap monitoring or an arbitrary date such as August 20th, when the majority of beetle flight is complete. Hauling restrictions are not

always necessary. Conditions within individual areas should be considered carefully before imposing such restrictions.

6. Access Development

Access is the key component to short- and long-term management of lodgepole pine to reduce damage caused by mountain pine beetle. Access is necessary to facilitate removal of infestations at an early stage and is necessary in uninfested areas to allow removal of susceptible hosts by hazard class. Access planning is a fundamental component of total chance development and should be closely linked to hazard ratings.

7. Beetle Proofing

Beetle proofing is simply a holding tactic, and does not eliminate the mountain pine beetle. This tactic will reduce the hazard of a particular stand or reduce the attractiveness to the beetles through partial cutting. Mature pine stands are spaced to reduce their susceptibility to mountain pine beetle attack for a short time period (1-10 years), until an accepted silvicultural treatment can be prescribed.

Beetle proofing is applicable in areas with little or no active infestation, or where maintaining a forest cover for other resource interests is more important than extracting the timber values. This treatment could be beneficial in watersheds, visually sensitive areas, parks, or sensitive wildlife/ fisheries areas where large opening size is less acceptable. The technique also has relevance in moderately or heavily infested management units where some tree cover must be maintained for reasons such as those listed above.

Not all stands are suitable for this treatment. The guidelines for selecting stands for beetle proofing produced by the U.S. Forest Service stress that pre-planning is critical. These guidelines should be followed carefully regarding criteria for selecting suitable stands and method of selective cutting. The application of beetle proofing is a short-term remedy for mountain pine beetle management and all other management considerations should be considered carefully before choosing this option. Beetle proofing should be done to hold stands intact until the normal cutting schedule can be resumed. Selective harvesting in lodgepole pine may have adverse consequences on other health aspects of the stand and site, such as increasing damage due to root disease and mistletoe.

Criteria for selecting stands for beetle proofing

When a TSA is faced with an epidemic, or impending epidemic of mountain pine beetle, partial cutting regimes should be considered in the overall strategy as an alternative to extensive clearcutting, or leaving large tracts of beetle-caused mortality. Partial cutting lodgepole pine stands is a

holding tactic for suitable stands until a regular harvesting and management cycle can be resumed.

Thinning appears to modify the micro-climate within the stand making it less desirable to the MPB. Studies have shown great reductions in tree losses due to mountain pine beetle following thinning, and yet there has been no consistent increase in tree vigour. The role of tree vigour in preventing successful beetle infestation continues to be debated, but it seems that the mountain pine beetle ignores tree vigour, especially during an outbreak. Thinning results in greater light intensity and wind movement, and reduction in humidity and insulation which deters beetles from stopping in these stands. As the crowns of lodgepole pine increase in size following thinning, shade and the accompanying micro-climate slowly revert back to an environment conducive once again to mountain pine beetle activity. Ongoing research recommends inter-tree spacing of 4.0- 4.5 m. The minimum recommended spacing is 3.5 m and in areas where threat of wind throw is low, 5.0 m spacing has demonstrated the best results (Fig. 16).

Figure 16. A stand that was beetle-proofed by the USDA Forest Service in South Dakota, USA.

The following guidelines provide site attributes to consider when evaluating a lodgepole pine stand for the application of "beetle proofing". The criteria are inclusive; that is, the stand is most suitable for this treatment when all given criteria are in effect.

1. **Slope:** Select stands with a slope of less than 35% to limit residual stand damage;

2. **Average Stand Diameter:** Select stands where average dbh is >20 cm, with fewer than 865 trees per ha > 12.5 cm dbh. These stands are more economical to log and residual stand damage is less;

3. **Age:** Select stands that are greater than 60 and less than 125 years old;

4. **Wind Firmness:** Select the most sheltered slope positions in relation to topography and prevailing wind patterns.

5. **Current Beetle Infestation Intensity:** Select stands with a current infestation rate of 10% or less. Higher levels may result in excessive mortality in left trees if logging is not completed prior to the next beetle flight;

6. **Vigour:** Select stands with crop trees have a live crown ratio of 30% or greater. Do not choose stands which have a root disease or dwarf mistletoe problem; and

7. **Landscape Level Management Objectives:** The prescription must be in keeping with all resource objectives for that BMU.

8. Silvicultural Treatments

A. Species manipulation

The creation of species mosaics within a management area will greatly reduce the level of potential loss in the next rotation. This practice is considered a long-term approach to reducing damage. Where possible, species other than lodgepole pine should be encouraged on sites after harvest. SPs must consider this option whenever alternate species are possible.

B. Age class manipulation

The creation of age class mosaics is considered to be a long-term approach to damage reduction. The intent is to reduce the amount of continuous, mature, susceptible lodgepole pine, thus dividing areas into units of varying ages. The creation of age class mosaics requires extensive pre-planning and also good access into all areas of the management unit. The placement of cut blocks with appropriate leave strips is part of a total chance development plan.

Table 5 lists the tactics discussed in the previous sections and the relevant strategies to which they can be assigned.

Table 5. Mountain pine beetle management tactics with corresponding strategies and critical dates for implementation.

MANAGEMENT TACTICS	STRATEGY NO[1].	CRITICAL DATES
1. SURVEY / ASSESSMENT		
Infestation Intensity Rating	2,3,4	September 1 - December 1
Hazard & Risk Rating	All	Any Time
Overview Flights	All	July 25 - August 10
1:50,000 sketch map	2,3,4	August 1 - September 15
1:12,000 Aerial Photos	2 (3,4)	August 1 - September 15
Ground recces	2,3,4 (5)	August 15 on
Ground probes	3,4	August 15 on
2. HARVESTING		
Sanitation	1,2,3,4	Any Time
Salvage	5 (6)	Any Time
High Hazard Host Removal	1,2,3	Any Time
Harvest Priority Rating System	2,3,4,5	Any Time
3. SINGLE TREE TREATMENTS		
Small Patch / Single Tree Selection	1,2,3,4	October 15 - July 15
MSMA	2,3,4	July 25 - September 5
(dependent on beetle flight)		
Fall and Burn	2,3	Any Time (in accordance with fire prevention regulations))
Preventive Insecticides	1,2	May - July
Debarking	2,3	September 1 - June 1
Helicopter Logging	1,2,3	October 15 - July 15
4. BAITING STRATEGIES		
Contain & Concentrate	2,3,4	May 1 - July 15
Monitoring	2,3,4	July 1 - September 1
5. HAULING RESTRICTIONS	2,3	July 15 - August 20
6. ACCESS DEVELOPMENT	All	Any Time
7. BEETLE PROOFING	3,4	August 30 - June 1
8. SILVICULTURAL TREATMENTS		
Species Manipulation	All	As Per Harvest
Age Class Mosaic Manipulation	All	As Per Harvest

[1] The strategies are as follows:

1. Prevention
2. Suppression
3. Maintain Low
4. Holding
5. Salvage
6. Abandon/Do Nothing

III. DEVELOPING A MOUNTAIN PINE BEETLE MANAGEMENT PLAN

The principles to reduce losses to the mountain pine beetle and other bark beetles are based on two approaches: 1) prevention (manipulation of forest cover and tree vigour), and 2) direct control (reduction of beetle numbers). As prevention is essentially a longer term strategy, existing infestations must be suppressed by direct control. The key characteristics of effective control programs are: 1) annual detection surveys in all susceptible stands; 2) early and thorough control activities on infestations, applying all relevant tactics in a co-ordinated manner; and 3) follow-up surveillance and control work for as long as required to reduce beetle numbers below injurious levels.

A mountain pine beetle management plan should be one component of a larger, more encompassing District or licensee Forest Health Management Plan. The goal of having a Forest Health and MPB management plan is to reduce mountain pine beetle damage and to manage the beetle within the AAC. This goal is achieved by implementing, by priority, appropriate strategies and tactics. A mountain pine beetle management plan should consider all resource values (timber, water, soil, recreation, fish, wildlife, etc.) in the development of operational plans and procedures. The objectives of a MPB Management Plan include, but are not limited to, the four points listed below.

1) Reduce epidemic mountain pine beetle populations to acceptable levels and control population build-up and spread through an annual monitoring program;

2) Sanitize affected stands to prevent spread of mountain pine beetle infestations and minimize future losses.

3) Salvage beetle-killed timber by harvesting in accordance with land use plans.

4) Reduce the susceptibly of lodgepole pine stands to mountain pine beetle by harvesting or modifying those stands that have a high hazard rating and, where ecologically sound, by creating a forest mosaic of diverse species and age classes.

Management within the allowable annual cut should be maintained by focusing control actions in infested stands, by removing or treating infested trees, or groups of trees, prior to the next beetle flight. Forest Health and MPB Management plans should be developed by district or industry forest health specialists for incorporation into higher level plans.

The MPB management plan is intended to be a decision making tool and

guide for managers in day-to-day forest activities. The information that follows is a guide for the development of this plan, but it will undoubtedly be improved upon as forest health programs evolve.

MPB Management Plans must be developed in conjunction with the land use objectives of the area. Within a MPB Management Plan area there can be one or many Beetle Management Units (BMUs). Strategies and tactics assigned to each BMU within an area must be appropriate for that BMU as well as adjacent areas. Information to be documented in this plan include:

- Allowable annual cut and long run sustainable yield;
- Community watershed objectives;
- First Nations liaison;
- Recreation and aesthetic values;
- Other uses i.e. grazing (number of animal unit months);
- Parks, Protected Areas;
- Wildlife habitat objectives; and
- Area susceptible lodgepole pine (hazard rating).

A BMU is a distinct management area where a consistent beetle management strategy is applied. Usually, BMU boundaries will coincide with other administrative or operational boundaries. The number of BMUs per District will vary, but should be between six and twenty. Using GIS technology, create the following base maps in order to delineate BMUs:

- Inventory compartments and forest cover information;
- Relevant planning units such as Community Watersheds, Licensee Operating Areas, Protected Areas, Parks, Ecological Reserves, First Nations Lands, TFLs, etc.
- Beetle information:
  - historic and current infestations;
  - hazard maps;
  - past treatments;
  - planned access; and
  - active cutting permits.

Determine and document the appropriate strategy and tactics for management of the mountain pine beetle within each BMU based on the beetle infestation status and other land use objectives. A guideline for the development of a MPB Management Plan is outlined on page 46.

1. Ranking BMUs

When all BMUs have been determined within a TSA. (District), the BMUs must be ranked relative to the available resources, beetle hazard and environmental concerns. In order that the most effective and efficient use be made of these resources, BMUs must be prioritized. The ranking or

Mountain Pine Beetle Management Plan
for the

District Priority:

1.0 TITLE PAGE
2.0 NAME OF BMU
3.0 MAP NO./REG./COMP.
4.0 GENERAL DESCRIPTION OF BMU
5.0 STATUS OF ADJACENT BMU'S:

BMU Name	Location relative to this BMU	Strategy Assigned
	N	
	S	
	E	
	W	

6.0 INVENTORY / DESCRIPTION (re: MPB Hazard and Risk)
7.0 MPB STATUS (historical / current)
8.0 RESOURCE ISSUES AND CONSTRAINTS
- 8.1 Access
- 8.2 First Nations
- 8.3 Wildlife / Biodiversity
- 8.4 Guiding and Trapping
- 8.5 Minerals
- 8.6 Range
- 8.7 Forest Health
- 8.8 Timber
- 8.9 Water

9.0 ACCESS
10.0 STRATEGY
- 10.1 Recommended
- 10.2 Implemented

11.0 SUITABLE TACTICS (responsibility and cost)
- 11.1 Budget (anticipated costs by tactic, dollars and manpower)
- 11.2 Proposed (planned *vs.* actual costs)
- 11.3 Accomplishments (planned *vs.* actual, activities and costs)

12.0 FIVE YEAR FOREST HEALTH PLAN
13.0 SUMMARY
14.0 RECOMMENDATIONS

prioritization of BMUs is a valuable exercise when resources are limited in terms of implementing the bark beetle management strategies prescribed.

The first step in the ranking process is to identify the following criteria:

1. Resource values: List only three and in order of priority;
2. Environmental concerns;
3. Area (ha) of susceptible stands / hazard rating;
4. Infestation size: As mapped from overview flights and/or based on ground surveys;
5. Control opportunity: Based on (1) and (2) above, control may not be an option; or may be limited to non-harvesting methods; and
6. Threat to other BMUs, based on (3) and (4) above.

The second step in the ranking process is to eliminate any BMUs in which no control action will occur. Next, the various resource values and combinations are weighted and ranked amongst themselves.

The third step is to rank according to risk. This will be based on the ratio of infestation size per susceptible area and threat to other BMUs. This does not necessarily mean that the largest infestations get the highest ranking. For example, a small ratio would mean a building population in an area of susceptible type. It would therefore be of prime concern to stop this infestation before it reached a size where management became more difficult.

Another ranking method could be based on the strategy (or strategies) assigned to the BMU. For example, a BMU assigned a Holding Action strategy would be ranked lower than a BMU which was assigned a Suppression strategy.

High ranking should be given to BMUs which have spot infestations of green attack with large areas of relatively clean, susceptible forest types. When allocating funds, these areas are the most cost effective in terms of control.

High ranking should also be given to BMUs which have large areas of green attack. Large infestations indicate some type of harvesting control strategy, usually combined with activities such as surveys and baiting. Table 6 is a form that could be used to rank BMUs by the factors listed above.

Table 6. BMU ranking form.

FACTORS	BMU NUMBER[1]						
	1	2	3	4	5	6	etc.
Resource Values a) b) c)							
Environmental concerns							
Susceptible area (ha)							
Infestation type & size							
Control opportunity							
Threat to other BMUs							
BMU strategy: a) Suppression b) Maintain Low c) Holding Action d) Salvage e) Abandon f) Prevention							

[1] Rank all factors using a 1-10 scale, with 1 being the highest ranking possible.

2. TIMING AND SCHEDULING

For a MPB Management Plan to be effective, the timing and scheduling of both field and office events is critical. The main activities and timing of events that should be considered are shown in Table 7.

Table 7. Annual schedule of mountain pine beetle management activities.

ANNUAL SCHEDULE OF FIELD EVENTS	
ACTIVITY	**TIMING**
DETECTION	
Beetle emergence	July 15 - August 31
Funnel trap monitoring	July 1 - September 15
Overview flight	
Pre-emergence	July (based on the first appearance of "faders")
Post-emergence	August (as early as possible - varies by area depending upon appearance of faders and red tops)
Ground recce	August 15 on
Detailed probe	September 1 on
CONTROL	
Baiting	May 1 - July 15
Single tree treatment:	
Fell and burn	October 15 - May 1
MSMA	July 25 - September 15
Priority harvest	As permitted (hauling restrictions at discretion of District Manager)
Infested inventory management	Storage of infested timber may be restricted at discretion of District Manager
MONITORING	
MSMA effectiveness	February 1 - May 15
Overwinter mortality	February 1 - May 15

ANNUAL SCHEDULE OF OFFICE ACTIVITIES	
ACTIVITIES	**TIMING**
PLANNING MEETINGS	
Baiting plan review	April 15
MPB Management Plan review	May and December
Recce responsibility assignment	Following post-emergence overview flight September 1
Control tactics	November 1-December 30
DATA SUBMISSION DATES	
Five year update	March 15
Annual report	
Licensee	March 15
District	March 31
Region	April 15
Ledger and map updates	September 15 on
Recce report/harvest schedule	October 31
BMU action plans	November 15
TSA control program	December 30

IV. DEFINITIONS

Accessible: Road access is adequate for harvesting or is guaranteed to exist within one year.

Aerial survey: Overview surveys are the initial recce/mapping flights designed to detect and delimit broad areas of beetle infestations throughout the Region (usually conducted from a fixed-wing aircraft at 1:100,000 scale). Detailed surveys are carried out annually to detect and delimit discreet pockets of beetle activity within a District or operating area (usually conducted from a rotary wing aircraft at a scale of about 1:20,000). 35 mm photography or use of GPS often employed during detailed bark beetle aerial surveys.

Aggregation pheromones: A pheromone which attracts conspecific individuals, usually of both sexes, to a given area.

BMU: A Beetle Management Unit is a planning and reporting unit for operational beetle management, where a consistent strategy is applied within a discreet area. The strategies chosen for each BMU must be compatible with those of adjacent BMUs.

Commensals: Two or more species of insect that live together, none of which is injured thereby, and one of which is benefited.

Conspecifics: Males and females of the same species.

Fall and burn: Infested trees containing live brood are felled, bucked, piled and burned, ensuring that the infested bark area is well burned. This is a sanitation procedure for lightly infested districts.

Grid baiting: Baits are placed throughout an affected stand with a 50 m grid spacing, beginning 25 m inside the stand perimeter. This technique is used to contain emerging beetles and prevent spread to adjacent susceptible areas.

Harvestable: Encompasses all considerations regarding the potential to harvest a stand. These include but are not limited to, operability, merchantability, and all concerns related to chance for harvest.

Hazard: The estimated susceptibility of a stand to bark beetle damage, given the stand and site characteristics. Hazard is calculated based on species, age class, stand density (basal area), elevation and latitude/longitude.

Licensee: Member of the forest industry who is a holder of any timber tenure agreement; funds by direct expenditure by appropriate licensee. The Small Business Forest Enterprise Program (SBFEP) is considered a licensee.

Patch infestation: An infestation greater than 1 ha containing a high ratio of attacked to unattacked trees (>100 green attacks per ha).

Patch *vs.* spot ratio: May be estimated by most recent aerial survey information and is intended to provide an idea of how the infestation should be managed within the BMU, i.e. Suppression or Holding strategy.

Percent of stands infested: Information derived from aerial surveys that estimates the area-wide degree of infestation using the following formula:

$$\% \text{ stands infested} = \frac{\#\text{ of inventory stand polygons with current mountain pine beetle attack}}{\text{total }\#\text{ of inventory stand polygons of susceptible types}}$$

The intent of this information is to consider the amount of infestation in relation to the amount of susceptible host material in the BMU. This calculation attempts to answer the question "Is the outbreak manageable?"

Pheromone: A chemical emitted by an organism which induces a behavioral or physiological response in another organism of the same species.

Probe: A formal evaluation of beetle activity within a stand, intended to obtain detailed information on infestation levels, history and stand data required to make management decisions.

Risk: The probability that an infestation will occur within a particular stand. Risk is dependent upon the proximity of beetle infestations to the stand in question. Generally, the higher the risk, the more likely the stand will be attacked.

Right-of-way baiting: Baits are placed at 25 m intervals along proposed right-of-ways 1 year prior to harvesting. If the right-of-way is not harvested as scheduled, all attacked trees must be removed or the beetles destroyed prior to beetle emergence. Recces must be done along, and adjacent to, all right-of-ways following beetle flight to identify any

additional MPB attack. These trees must be removed or the beetles destroyed prior to beetle emergence whether or not the right-of-way has been harvested. In pine types, where there is no evidence of mountain pine beetle attack, right-of-way baiting is not recommended.

Salvage harvesting: Stands identified as being suitable for salvage are those where harvesting will not contribute significantly to beetle population reduction. The removal of currently infested trees is incidental to the control effort or the extraction of dead material. Salvage criteria include the levels of grey, red, green attack and the amount and size of susceptible host material remaining. Salvage stands are those where the infestation has virtually run its course and where beetle production is likely to be less than replacement e.g. a decrease in green to red ratio. Suggested criteria for identifying stands for salvage are as follows:

grey + red + green attack	>45%
pine volume remaining	<40%
average dbh of remaining pine	<15 cm.

Sanitation harvesting: Removal of infected or infested dead or damaged trees, or of susceptible trees, to prevent or reduce the spread of the infestation. Sanitation harvesting is intended to remove currently infested trees where beetle life stages still remain under the bark. This is the most efficient form of beetle management. The objective is to reduce residual beetle populations available for subsequent attack within the stand or in adjacent susceptible stands.

Salt and pepper infestation: Infested trees (green or red attack) are distributed uniformly or randomly throughout a stand or area. No discrete clumping is noticeable. High intensity "salt and pepper" attack is usually indicative of an advanced infestation. Low intensity "salt and pepper" attack indicates a new and building infestation.

Semiochemical: A chemical involved in communication between organisms.

Spot baiting: 1 to 4 baits placed strategically within a small epicentre of attacked trees. This baiting method is to be used on spatially discrete pockets of attack which will be dealt with by some method of harvesting or single tree disposal, e.g. single tree extraction; MSMA; fall and burn.

Spot infestation: Infested trees (green or red attack) are spatially clumped in recognizable epicentres. This condition is normally found when outbreaks are beginning in a previously uninfested stand or drainage. Any infestation with an area of one hectare or less and comprised of no more than 100 currently infested trees.

Strategy: A collection of tactics or treatments compiled in a plan to achieve a management goal.

Tactic: A method or treatment for accomplishing an end.

TFL: Tree Farm License (area based tenure).

Vacant crown land: Includes all areas not within a woodlot license, TFL, or under the management of another agency (e.g. Provincial and Federal Parks).

Walk through survey: A non-systematic, low intensity type of ground survey for bark beetle damage. Usually, only qualitative estimates of insect and stand data are taken. Used to make initial assessment and confirm aerial survey information.

APPENDIX I

DETERMINATION OF RESPONSIBILITY

The responsibility for bark beetle management lies with Ministry of Forests District Managers, forest licensees and other land managers. The determination of licensee responsibility is identified in the *Forest Act*, the *Forest Practices Code of British Columbia Act*, and sections in the *Forest Practices Code of British Columbia Act*, Operational Planning Regulations. Responsibilities are assigned in the following matrix according to the funding source. The intent of the *Forest Practices Code of British Columbia Act* is to clarify and standardize the responsibilities of the licensees in carrying out specific bark beetle related management activities upon a defined land area where the licensee has a medium- to long-term interest in preserving timber supplies.

All activities pertaining to bark beetle management must now be included in the forest development plans. Acknowledgment of the responsibilities between ministry and licensee must be agreed upon prior to submission of the beetle management plan. All control or beetle management plans are subject to review and approval by the District Manager who has the authority to accept or modify the guide to meet overall management objectives.

Bark Beetle Responsibility Matrix

Activity	Tenure				
	Private Lands	Woodlots	SBFEP	Forest License	Other Crown Lands
1. SURVEYS					
aerial					
overview	BCFS	BCFS	BCFS	BCFS	BCFS
detailed	BCFS	BCFS	LICENSEE[2]	LICENSEE[2]	BCFS
photos	BCFS	BCFS	LICENSEE[2]	LICENSEE[2]	BCFS
ground					
walk through	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS
probe	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS
2. TREATMENT					
pheromone placement[1]	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS
trap trees					
conventional	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS
lethal	OWNER	BCFS	LICENSEE[2]	LICENSEE[2]	BCFS
fall & burn	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS
single tree removal	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS
MSMA (post attack)[1]	OWNER	BCFS	LICENSEE[2]	LICENSEE[2]	BCFS
3. PREVENTION					
hazard rating	OWNER	BCFS	BCFS	BCFS	BCFS
monitoring	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS
blowdown salvage	OWNER	LICENSEE	LICENSEE[3]	LICENSEE[3]	BCFS
access	OWNER	LICENSEE	LICENSEE[3]	LICENSEE[3]	BCFS
slash abatement	OWNER	LICENSEE	LICENSEE[2]	LICENSEE[2]	BCFS

1. These activities may be recognized through appraisal cost estimates.
2. The area of responsibility will include any accessible area within 400 metres of proposed or existing roads or blocks identified in the Forest Development Plan and any other block still under licensee obligation.
3. The area of responsibility is to include all lands falling within a Forest License boundary, commonly referred to as Operating Area and does not include lands covered by another tenure.

V. REFERENCES

Borden, J.H. 1982. Aggregation Pheromones. In Bark beetles in North American conifers: a system for the study of evolutionary biology. Edited by J.B. Mitton and K.B. Sturgeon. pp. 74-139.

Borden, J.H., L.J. Chong, B.S. Lindgren, E.J. Begin, T.M. Ebata, L.E. Maclauchlan and R.S. Hodgkinson. 1993. A simplified tree bait for the mountain pine beetle. Can. J. For. Res. 23: 1108-1113.

Bright, Jr., D.E. 1976. The Insects and Arachnids of Canada Part 2. The Bark Beetles of Canada and Alaska. Coleoptera: Scolytidae. Biosystematics Research Institute, Research Branch. Can. Dept. Agric. Ottawa, Ontario, Canada. Publ. 1576.

Furniss, R.L. and V.M. Carolin. 1980. Western Forest Insects. USDA. For. Serv. PNW-FRES Misc. Pub. No. 1339. 654 pp.

Lindgren, B.S. 1992. Analyses of mountain pine beetle funnel trap data in Penticton FD, 1989-1992. Summary Report for BCFS, Penticton District. 27 pp.

Safranyik, L., D.M. Shrimpton and H.S. Whitney. 1980. Management of lodgepole pine to reduce losses from the mountain pine beetle. Can. For. Serv. PFRC For. Tech. Rep 1. 24 pp.

Ministry of Forests. 1995. Forest Practices Code of British Columbia Bark Beetle Management Guidebook. British Columbia, Min. of Forests II. BC Environment III. Series.

Stark, R.W. 1982. Generalized ecology and life cycle of bark beetles. In Bark beetles in North American conifers: a system for the study of evolutionary biology. Edited by J.B. Mitton and K.B. Sturgeon. pp. 21-45.

Shore, T.L. and L. Safranyik. 1990. A system for rating the susceptibility and risk of lodgepole pine stands to mountain pine beetle. For. Can. PFC-File Rep. 5203. 17pp.